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COMPARATIVE STUDY OF ELECTRICAL MOTORS FOR CEILING FAN APPLICATION

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ABSTRACT

This paper deals with the comparison of various motors that have been used for ceiling fan application. Ceiling fan is mostly driven by the single induction motor with an efficiency of 30%. The BLDC motor is popular now a days for a high efficiency, compactness and controllability. The single phase induction motor and BLDC motor performance in ceiling fan application is compared considering Torque speed characteristic, speed regulation efficiency and effective cost. A MATLAB Simulink model of ceiling fan using BLDC motor is modelled and simulated.

Keywords*:* Brushless DC motor (BLDC), Capacitive Start Capacitive Run Induction Motor, Efficiency, Speed Regulation, Universal Motor

1. INTRODUCTION

A ceiling fan used to reduce the stratification of warm air in a room by forcing it down to affect both occupant's sensations and thermostat readings, thereby improving climate control efficiency. A fan is mostly doomed for getting air to people occupying a office, public places, building, shops or residential complex etc and therefore directly impacting the human comfort by temperature control. Ceiling fan circulates the air in room and provides the pressure required to push it. The fan has become a vital support for many applications like shop ventilation, material handling, boiler usage etc. In the manufacturing sector, fans use about 78.7 billion kWh of energy every year which is approximately 15% of the electricity used by motors.

The first ceiling fans appeared in the early 1860s and 1870s, in the United States. Since then there are various motors used to drive ceiling fan. The motors that has been used for development of

ceiling fan are dc motors, induction motors, heavy-duty oil bath motor, universal motors, etc. Now a day single phase capacitive start capacitive run Induction motor is widely used for the application of ceiling fan.

In this paper, the performance of various motor for the application of ceiling fan is compared and discussed with their performance characteristic. A MATLAB Simulink model developed of ceiling fan using BLDC motor and compared with single phase I.M ceiling fan.

2. DIFFERENT MOTORS USED FOR CEILING FAN

2.1 Single phase Capacitive start capacitive run induction motor

Ceiling fan application uses a single phase induction motor. Basically, this motor is not self-starting. It requires external force to run it during starting and this property of the single induction motor is explained by the double field revolving theory. A capacitor is used to overcome this drawback. It is connected across a part of the winding in the fan motor which creates a phase difference between the windings one part with the capacitor connected and other part without the capacitor. As a result, a field is produced which is resultant of the two fields. This rotor rotates according to the direction of the resultant field. The capacitor may be connected via centrifugal switch to increase the efficiency of the fan. The single phase capacitive start capacitive run induction motor is developed for a low torque operation mostly ranges from 0.22 to 0.72 N-m depending upon the size of blade. The induction motor being low cost and high value is mostly used. The fan blade size are in the range of 800, 900 and 1200 mm A 18 or 16 pole single phase induction motor is used in a ceiling fan giving a speed range from 50 rpm to 330 rpm.[1]

2.2 Universal Motor

The Universal motor are rarely used for ceiling fan application. For the application of ceiling fan, a Universal motor is developed with an 18 poles. A Universal motor is also called as an AC series motor. High starting torque is developed in this Universal motor and can be operate from 25 to 60 Hz. The Universal motor has a deep rotor bars for better starting purpose. The torque of 0.4 N-m is provided by this motor and air flow output of this fan is 270 M^3/min. As the motor has a less efficiency and make more noise this motor is rarely preferred in ceiling fan application. Universal motor has 1.0 service factor which means the motor can operate at 100% of its rated horsepower. The Universal Motor ceiling fans are heavy and bulky

Table 1: Comparison of single phase induction motor and universal motor

Parameters	Single phase induction motor	Universal motor
Motor power	55-78W	80-110W
Operating voltage	230V AC	230V AC
Speed Min- Max-	50 320	80 320
Speed controller	Smooth triac	Resistive
Weight	3-6 Kg	7-10 Kg
Noise	70 dB	130 dB
Efficiency	30%	22%
Air Flow	270 CFM	270 CFM
Service factor	1.15	1.0

3. MATLAB MODEL FOR BLDC MOTOR

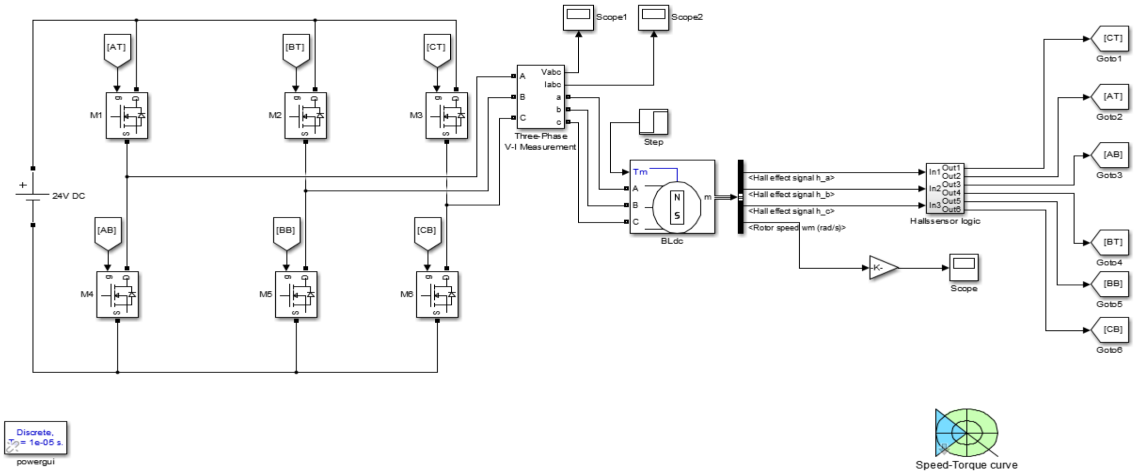


Fig. 1: MATLAB model for BLDC motor

The whole system is comprised of following parts:

a. The main power circuit: Constant DC voltage source of 24V to driver circuit.

b. The motor: Brushless DC motor with a trapezoidal waveform is used.

c. Measurement unit: This unit consists of bus selecting module "Bus selector," which is used to measure the variables of the motor when it operating such as back EMF, current, rotor speed, torque etc.

d. Logic unit: This unit consists of logical operator AND/NOT which are used for generating gate pulse signals for driving circuit.[2]

The basic parameters used in this models are as specified in table:

Table 2: Basic parameters used in MATLAB models

Phase resistance	2 Ohm
Phase inductance	3 mH
Number of slots	18
Voltage constant	40 kV/rpm
Number of poles	16
Number of phases	3
Voltage input	24 V
Power input	40 W

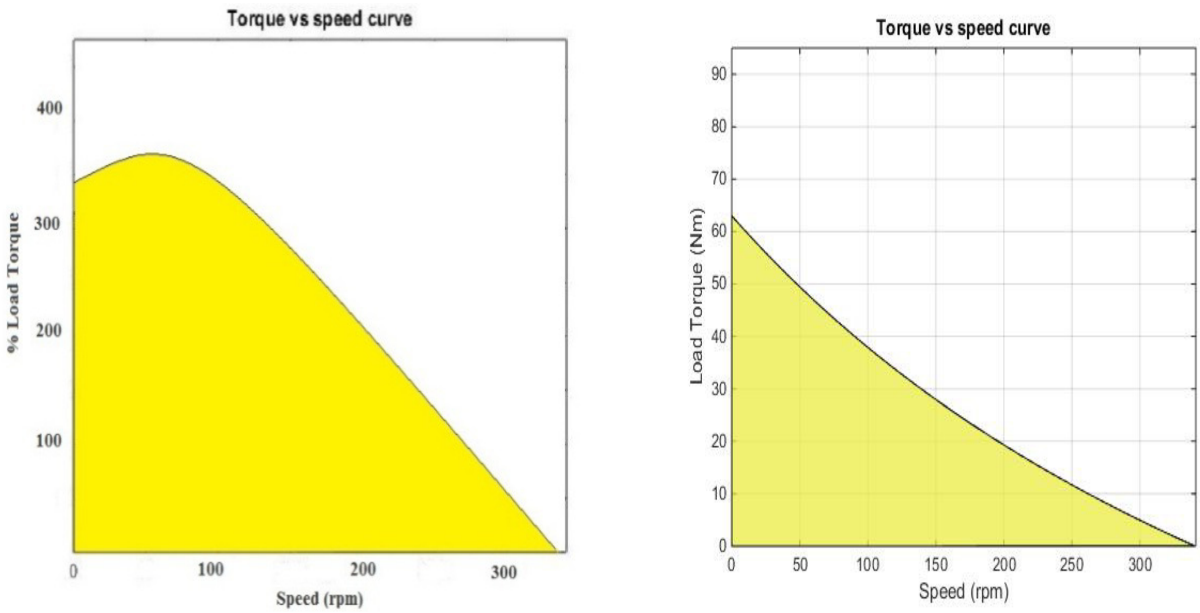
4. PERFORMANCE ANALYSIS

A traditional Ceiling fan implies single phase induction motor or shaded pole motor or split phase permanent capacitor or capacitive start capacitive run. This motors are designed for lower speed with winding wound for 16, 18, 20 or 22 poles. A traditional ceiling fan mostly used now a days are of power rating 70 to 80 W. The single phase IM ceiling fan rotates with a maximum RPM of 370 giving airflow from 250 to 300 M^3/min. The rotor resistance is very high for wide speed control range using stator voltage regulator. In Indian scenario, the lowest air delivery to achieve 5-star energy rating is 210 M^3/min, i.e. if the Fan draws 52.5 W or less then it is qualified for 5-star energy rating. But unfortunately the limitation dwells with this Induction motor.

The typical ceiling fan uses capacitive or resistive regulation for speed control purpose as a result its efficiency is lowered to certain extent. In addition the RPM control is by controlling the voltage and the voltage fluctuations of the mains make it very challenging to have constant RPM based on the AC mains supply. They are usually low-cost machines and operated at high slip, therefore, the ceiling fan have poor performance. The single phase induction motor parameters are studied from existing system. The MATLAB model is developed for study of BLDC ceiling fan.[3]
Performance evaluation of single phase induction motor and BLDC motor:

The comparison analysis of recent used ceiling fan i.e. single phase induction motor ceiling fan and proposed brushless DC ceiling fan is stated in as below.

4.1 Torque vs speed characteristic



(a) **(b)**

Fig. 2: Torque Speed characteristic of (a) Single phase induction motor (b) BLCD motor

The Torque speed characteristic of a 1ph capacitive start capacitive run induction motor is shown in Fig. 2 (a) and BLDC motor Torque speed characteristic is shown in Fig. 2 (b) . The Starting torque is nearly 300 to 400% of capacitive start capacitive run while in BLCD motor the starts from nearly 60 to 70% of total torque. As a resulting of this starting current of traditional ceiling fan is nearly twice to that of BLDC ceiling fan. There is a zero torque getting at the maximum speed of ceiling fan for both single phase induction motor and BLDC motor. Thus both the motors give same characteristic BLDC motor hence can be employed.[4]

4.2 Speed Regulation Characteristic

The speed control of ceiling fan with single phase induction motor is controlled by the TRIAC based controller. The Induction Motor employs for ceiling fan application thereby smooth controlling is possible.

Fig. 3: Speed Regulation Characteristic of single phase induction motor

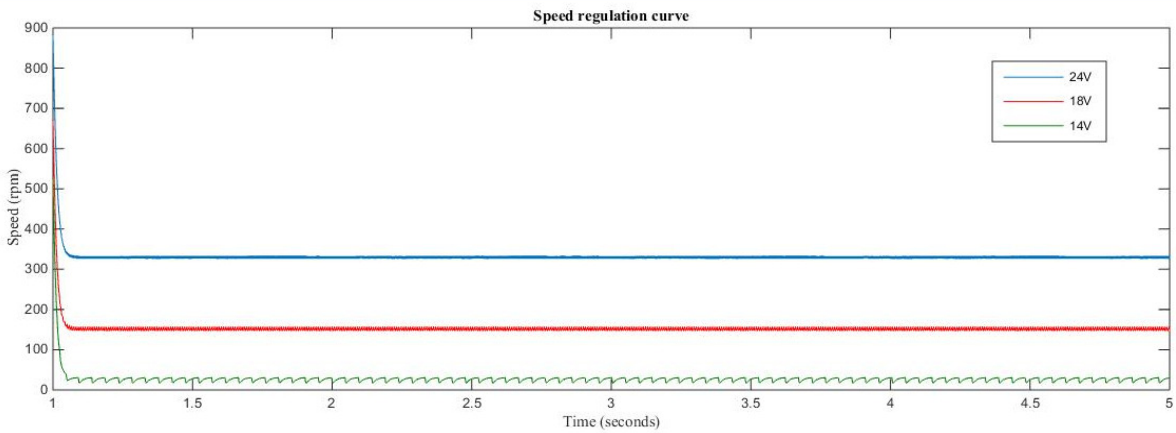


Fig. 4: Speed Regulation Characteristic of BLCD motor

The speed regulation curve of single phase induction motor ceiling fan is shown in the Fig. 3. The variation of speed can be easily obtained by the TRIAC controlling. The BLDC motor as which run on 24 V dc supply has a minimum operating voltage of 12V DC. Thus speed control of a motor can be operated with least speed variation. Thereby smooth speed regulation is not possible as shown in Fig. 4. As a result, the speed control is done with the changing the supply voltage or changing the firing angle. The speed of operation of BLDC ceiling fan is either slow, medium or high.

4.3 Output Air Flow

The total amount of air flow or displacement is based on the blade size & rpm and does not change due to any other factor. The proposed solution is to keep the same air flow or displacement with less of energy usage along with improving the PF using the BLDC motor based ceiling fans. Typical BLDC motor based ceiling fan has much better efficiency and excellent constant RPM control as it operates out of fixed DC voltage.

4.4 Energy efficiency

According to IS standards the energy rating is calculated as the ratio of air flow in m^3/min and the input power in watt of total energy rating. For a single phase induction motor 72 W ceiling fan of an air density of 270 m^3/min, the energy star rating is calculated as 270/72 which is nearly 3 star rating. The BLDC motor with 24 W power input with the same air flow of 270 m^3/min gives a 5 star rating. As a result, BLDC fan is more energy efficient.

4.5 Cost

The BLDC motor has higher motor cost due to the presence of Magnet, Electronics and Sensors, whereas the induction motor has much lower cost compared to that of BLDC ceiling fan.[5]

5. CONCLUSION

The various comparisons has been done between the single phase induction motor and BLDC motor fan. For the energy conservation purpose the new proposed BLDC fan motor should be developed and used for the ceiling fan application. Though the speed regulation is not smooth still BLDC motor gives better performance than the single phase induction motor. The efficiency has also been increased by nearly 30% to 40%.

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